IN THE UNITED STATES
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Statement of Translation Accuracy

I hereby certify that the accompanying translation is a true and accurate translation of the application identified by DeMont & Breyer's Attorney Docket as **9771-014US**, Serial No. **10/598981**, Filed on **15 September 2006.**

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patent Application

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Docket:	9771-014US
Title:	Means of locomotion having improved flow properties

Commissioner for Patents
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SIR:

Enclosed are the following papers relating to the above-named application for patent:

Transmittal Letter
English Translation of International Application
Statement of Translation Accuracy
Preliminary Amendment

Pursuant to 37 C.F.R. 1.136(a)(3), please treat this and any concurrent or future reply in this application that requires a petition for an extension of time for its timely submission as incorporating a petition for extension of time for the appropriate length of time.

Respectfully,

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Means of locomotion having improved flow properties

Description

The invention relates, in general, to means of locomotion and, in particular, means of locomotion, along the surface of which a medium flows, the medium being capable of comprising a gas, a liquid or a mixture of gas and liquid.

It is known that the flow properties of a means of locomotion which moves in a medium depend on a series of parameters. These include, inter alia, the properties of the medium, the form of the means of locomotion and the relative speed of the means of locomotion and medium.

Particularly in order to reduce the flow resistance and as far as possible avoid other adverse flow properties, vehicle manufacturers expend a great amount of time and high costs to achieve an ever-increasing optimization of the geometry of vehicles. This refers to a different extent to land craft, watercraft and aircraft. However, there are limits to suppressing specific adverse flow effects by the adaptation of the vehicle geometry.

Pressure compensation at the rear end of a moved object gives rise, for example, to what are known as drag eddies. Even in the transitional phase between laminar and turbulent flows, it may happen that high drag eddies form due to the breakaway of the laminar flow. The generation of such uncontrolled high drag eddies requires energy and therefore leads to a considerable braking action.

This is a problem particularly in aeronautics, since such high eddies persist in stable form for a lengthy period of time and consequently may be detrimental to following aircraft. Drag eddies are, however, likewise to be observed also where land craft and watercraft are concerned.

A further problem is the formation of leeward rolls under crosswind. These are high eddies which form on that side of an object which faces away from the wind. Due to the pressure difference which occurs, this leads, particularly in the case of high-speed trains, to an increased risk of tilting of the train.

Furthermore, the formation of turbulent eddies entails, as a rule, a high generation of noise and of vibration.

The object on which the invention is based is to indicate a novel way in which the flow properties of a means of locomotion which moves in relation to a surrounding medium can be improved and the adverse effects described above can be reduced.

The object is achieved in a surprisingly simple way by means of a subject according to one of the appended independent claims. Advantageous embodiments and developments are described in the subclaims. The inventors surprisingly found that, in means of locomotion, the surface of which has at least partially a special three-dimensional surface structure, such as is described in EP 92 911 873.5, PCT RU92/00106 and in EP 96 927 047.9, PCT/EP96/03200, not only is the flow resistance reduced, but further adverse flow effects are also reduced. The disclosure content of EP 92 911 873.5,

PCT RU92/00106, and of EP 96 927 047.9, PCT/EP96/03200, is therefore expressly incorporated herewith by reference.

Accordingly, a means of locomotion according to the invention comprises at least one surface which has a structuring with a multiplicity of depressions and/or elevations, a surrounding medium flowing along this surface during the movement of the means of locomotion.

Advantageously, the at least one surface is designed in such a way that vortexes form in the surrounding medium in the vicinity of the surface when the medium flows along the surface.

The generation of vortexes in the vicinity of the surface in the surrounding medium by means of a depression according to the invention can be described as follows. At the depression, first, an eddy roll forms essentially transversely with respect to the flow direction. Since this eddy roll typically has a nonvanishing helicity, the medium is sucked into the eddy at one end and is ejected at the other end. The result of this is that the last-mentioned end of the eddy comes loose from the surface and is entrained by the main flow. Vortexes thereby form, which, starting from the depressions, lead away from the surface in the direction of the main flow. Since the pressure within the vortexes is lower than in their surroundings, the boundary layer of the medium in the vicinity of the surface is sucked away and conducted into the main flow. Each eddy consequently acts as a kind of boundary layer controller which sucks into itself the surrounding medium, even counter to the prevailing flow direction, in all the directions of the surroundings. Unordered turbulences present

in the medium are thereby broken down in the vicinity of the surface.

Owing to the formation of vortexes, as described, the flow breakaway is displaced rearward along the flow direction, as compared with a smooth surface, and the adverse flow effects described above, such as the formation of drag eddies or of leeward rolls, are reduced. The reduction in the formation of drag eddies also leads at the same time to a reduction in the overall resistance.

Advantageously, the depressions and/or elevations have a two-dimensionally delimited edge and, particularly advantageously, are rounded in the region of the edge in relation to the rest of the surface with a predetermined rounding radius. The rounding radius may in this case have a different value in different directions within the plane of the surface.

Preferably, the depressions are essentially in the form of a segment of a sphere or of an ellipsoid, since this form is the simplest to implement in production terms.

The form, size and arrangement of the depressions and/or elevations may advantageously be coordinated with different flow conditions which are predetermined by the intended use of the means of locomotion. In order to implement a flexible adaptation of the surface structure of the means of locomotion to different states of movement during use, the means of locomotion advantageously comprises a device for varying the form and/or number of the depressions and/or elevations. This may take place, for example, by means of flexible membranes,

as described in EP 96 927 047.9. EP 96 927 047.9 is therefore also expressly incorporated herewith in this regard by reference.

In a preferred embodiment, the depressions and/or elevations are arranged at least partially essentially periodically on the surface of the means of locomotion.

In order to achieve as complete an area covering as possible by means of the structuring, that surface of the means of locomotion which has the depressions and/or elevations expediently comprises at least one first, essentially planar region and at least one second, essentially curved region. The structured surface can thereby be adapted to any desired geometries of the means of locomotion.

Since different flow states typically prevail in the planar and the curved region of the surface of the means of locomotion, the depressions and/or elevations advantageously differ from one another in these regions in form and/or size and/or arrangement.

In a particularly preferred arrangement of the depressions and/or elevations in an essentially planar region of the surface of the means of locomotion, the center points of three directly adjacent depressions and/or elevations form an equilateral triangle, the spacing of the center points of two adjacent depressions and/or elevations having an essentially constant first value and the spacing of two successive rows of depressions and/or elevations having an essentially constant second value. In a curved region, the surface preferably has a

similar arrangement which takes the surface curvature into account.

A preferred design of a means of locomotion according to the invention comprises a land craft, in particular a rail vehicle or a heavy goods vehicle or passenger car, with at least one outer casing, at least parts of the surface of the outer casing having a multiplicity of depressions and/or elevations.

Particularly preferably, the surface of the means of locomotion has a multiplicity of depressions and/or elevations in such a way that the formation of leeward rolls is reduced, as compared with an otherwise identical means of locomotion, the surface of which has a smooth structure. This is particularly advantageous when the means of locomotion is designed as a rail vehicle, in particular as a high-speed train.

A further preferred design of a means of locomotion according to the invention comprises an aircraft, in particular an airplane or helicopter, with an least one of the components comprising an outer casing, propeller, rotor, turbine, wing, airfoil or tail unit, at least parts of the surface of one of these components having a multiplicity of depressions and/or elevations.

A preferred design of a means of locomotion according to the invention is also a watercraft comprising at least one hull and/or one propelling screw, at least parts of the surfaces of the hull and/or of the propelling screw having a multiplicity of depressions and/or elevations.

Furthermore, any other desired types of means of locomotion, such as, for example, surfboards, bobsleighs or rockets, with a surface which has a multiplicity of depressions and/or elevations, also come within the scope of the invention.

Particularly preferably, by means of that surface of the means of locomotion which has a multiplicity of depressions and/or elevations, as compared with an otherwise identical means of locomotion, the surface of which has a smooth structure,

- the formation of drag eddies is reduced and/or
- the formation of leeward rolls is reduced and/or
- the flow resistance is reduced and/or
- the position of the flow breakaway is displaced rearward in relation to the direction of movement of the means of locomotion and/or
- the generation of noise is reduced and/or
- the generation of vibration is reduced and/or
- the deposition of particles on the surface is reduced and/or
- the formation of ice on the surface is reduced.

Accordingly, the invention also embraces the use of a surface which has a multiplicity of depressions and/or elevations as a surface or part of a surface of a means of locomotion for one or more of these purposes.

Furthermore, the invention embraces a layer, in particular designed as a film, for application onto a surface or parts of a surface of a means of locomotion, the outside of the layer having a structuring which comprises a multiplicity of depressions and/or elevations. By such a layer being applied,

the advantages according to the invention can be achieved even by the retrofitting of conventional means of locomotion.

The invention is explained in more detail below by means of preferred exemplary embodiments, with reference to the accompanying drawings, identical reference symbols referring to identical or similar components in the individual drawings in which:

figure 1 shows a diagrammatic illustration of a first embodiment of a means of locomotion according to the invention,

figure 2 shows a diagrammatic illustration of a second embodiment of a means of locomotion according to the invention,

figure 3 shows a diagrammatic illustration of a third embodiment of a means of locomotion according to the invention,

figure 4 shows a diagrammatic illustration of a propelling screw of a means of locomotion according to the invention,

figure 5 shows a diagrammatic illustration of a rotor of a means of locomotion according to the invention,

figure 6 shows diagrammatically the cross sections of two wings,

figure 7 shows diagrammatically a central cross section through a first embodiment of a depression or elevation perpendicularly with respect to the surface,

figure 8 shows a diagrammatic illustration of a first distribution of depressions or elevations,

figure 9 shows diagrammatically a central cross section through a second embodiment of a depression or elevation perpendicularly with respect to the surface,

figure 10 shows a diagrammatic illustration of a second distribution of depressions or elevations,

figure 11 shows diagrammatically a central cross section perpendicularly with respect to the surface of a third embodiment of depressions or elevations in the corresponding top view,

figure 12 shows a diagrammatic illustration of an embodiment of a surface with depressions or elevations which has planar and curved regions.

Fig. 1 shows a high-speed train 10, the outer surface 101 of which has a multiplicity of depressions. During the movement of the train, as a result of the mechanism described above, secondary vortexes are generated, starting from these depressions, in the air which flows along the surface. Due to these self-organizing vortex structures, the boundary layer in the vicinity of the surface is sucked away and conducted into the main flow, with the result that the flow resistance is reduced and various adverse flow effects are also reduced. It is particularly important, here, to have a reduced formation of leeward rolls under a crosswind, which represents a serious problem in conventional high-speed trains.

Fig. 2 shows a conventional jet plane 20. In this exemplary embodiment, the surfaces 201 of the wings 22 have a structuring with a multiplicity of depressions and/or elevations. This structuring may be provided during the production of the wings or else be generated by means of a

subsequently applied layer, for example by the application of a film which has the structuring. The structured surface may, of course, also be provided advantageously on further surfaces of such an airplane, such as, for example, the fuselage 21, the rear tail units 23 and 24 or the outside of the propulsion systems 25. For example, the turbine blades of the propulsion systems 25 could also have a surface structured according to the invention. Advantageous effects of an aircraft according to the invention are, for example, a reduction in the formation of drag eddies and an improvement in the stall properties. Moreover, the invention reduces a problem, arising particularly in supersonic aircraft, of the heating of the outer casing owing to a marked reduction in the surface resistance. At the same time, due to the surface structuring according to the invention, the heat transfer between surface and medium is improved, this likewise contributing to a reduction in this problem.

Fig. 3 shows a ship 30, in which that surface 301 of the hull 31 which lies below the water line 40 has a structuring with a multiplicity of depressions. Moreover, a surface 331 structured according to the invention may also be provided on the blades 34 of the propelling screw 33. This is also illustrated in detail in fig. 4.

Fig. 5 shows a rotor 50 of a helicopter according to the invention, with two rotor blades 51, the surface 501 of which has a multiplicity of depressions and/or elevations. In this exemplary embodiment, too, the flow properties can thereby be influenced positively. In helicopters, this has the effect, in particular, of improved lift, improved stall properties and a

reduction in the generation of noise. The stall properties of a propeller may also be improved in the same way.

Fig. 6 shows the cross section through a profile of a conventional wing 26. The elongate profile is required in order to avoid a premature flow breakaway which would lead to a loss of lift. If, however, the surface of a wing has a multiplicity of depressions and/or elevations, the flow breakaway point is displaced rearward along the flow direction, with the result that entirely novel wing profiles become possible. Such a profile 27 is illustrated by way of example in fig. 6, laid over the conventional profile 26 for comparison. By means of such novel wing profiles, the lift can be increased significantly or, if the lift remains the same, the dimensions of the wing can be markedly reduced.

Figure 7 shows a central cross section through a preferred form of a depression 602 perpendicularly with respect to a planar surface. In this exemplary embodiment, the depression 602 is in the form of a segment of a sphere or of a spherical cap with a radius R_1, a height h and a diameter d, and is rounded with a rounding radius R_2. In this example, a depression is rotationally symmetrical with respect to an axis of rotation through the center point of the depression perpendicularly with respect to the surface.

Fig. 8 illustrates a preferred distribution of the depressions 602 on a planar surface. The depressions 602 are arranged periodically, the center points of three directly adjacent depressions 602 forming an equilateral triangle. The angle á therefore amounts to 60°. The spacing of the center points of two adjacent depressions 602 and consequently the side length

of said triangle amount to t_2. The spacing of two successive rows of depressions 602 and consequently the height of said triangle amount to t_1. t_1 and t_2 may have different values, depending on the intended use.

Figure 9 shows a central cross section through a further preferred form of a depression 702 perpendicularly with respect to a planar surface. In this exemplary embodiment, the depression 702 is in the form of a segment of an ellipsoid with the diameters E_1, E_2 and E_3, E_3 lying perpendicularly with respect to the drawing plane and accordingly not being illustrated. The depression has a height h and a diameter d and is rounded with a rounding radius R_3.

Fig. 10 illustrates a preferred distribution of the depressions 702 on a planar surface. This corresponds essentially to the arrangement illustrated in fig. 8 for the depressions 602.

Further advantageous forms and arrangements of the depressions and/or elevations may be gathered from the applications EP 92 911 873.5, PCT RU92/00106 and EP 96 927 047.9, PCT/EP96/03200. Accordingly, the surface advantageously has a three-dimensional structure, such as is illustrated diagrammatically by way of example in fig. 11, with depressions or elevations 802, curved zones and transitional zones. In the cross section through the surface, as illustrated in the upper region of fig. 11, the depressions or elevations extend along its diameter d, the curved zones along the extent l_c and the transitional zones along the extent l_{tr}. The spacing of two depressions is again designated by t_2.

Any portion of the depressions or elevations 802 along the surface has the configuration of a smooth and continuous line which can be described by the following relation:

$$r(\varphi,z)=\left(\frac{z}{h}\right)^{k}\left[r(h,0)-\frac{l_c}{2}+\Delta r\left(\frac{\varphi}{180^\circ}-\frac{1}{4\pi}\sin\frac{4\pi\varphi}{180^\circ}\right)+\right.$$

$$\left.+A_1\Delta r\left(\sin\frac{\pi\varphi}{180^\circ}-\frac{1}{3}\sin\frac{3\pi\varphi}{180^\circ}\right)+A_2\Delta r\left(\sin\frac{2\pi\varphi}{180^\circ}-\frac{1}{2}\sin\frac{4\pi\varphi}{180^\circ}\right)\right], \qquad (1)$$

in which:

r (φ,z) is the portion radius in the direction of the angle φ (in angular measurement), which is to be counted from the extent which connects the centers of adjacent depressions and/or elevations or from any extent which lies in the marked portion;

- z is the portion height above the lowest point of the depressions or the portion spacing from the highest point of the elevations;
- *r(h,0)* is the radius of the depression portion or elevation portion in the direction of the angle φ = 0°;
- $\Delta r = r(h,180°)-r(h,0°)$ is the difference between the radii of the depression portion or of the elevation portion in the direction of the angles φ = 180°C and φ = 0°C;
- l_c is the dimension of the curved region, projected onto a plane which runs parallel to the plane of the surface;
- k is a coefficient with 0.3 < k < 0.7;
- A_1 is a coefficient with $-1 < A_1 < 1$;
- A_2 is a coefficient with $-1 < A_2 < 1$; and
- h is the depth or height of the depressions or elevations.

In the curved zones, the depressions or elevations are advantageously rounded with a rounding radius of $R > 3.h$ with respect to the transitional zones.

The value of h advantageously lies between 0.005 and 0.3 times the thickness of the boundary layer. Moreover, with d being the diameter of the depressions or elevations, preferably the following relations apply:

$2 \cdot h < d < 40 \cdot h$, in particular $2 \cdot h < d < 10 \cdot h$,
$0{,}3 \cdot d < l_C < 0{,}5 \cdot d$
and $0{,}05 \cdot d < l_{tr} < 3 \cdot d$.

The parameters contained in equation (1) may be selected differently as a function of the type of medium, the form and dimensions of the surface, the flow velocity, the temperature of the medium and the surface and also further factors influencing the flow.

Fig. 12 shows a surface which has at least one planar region 601 and one curved region 901. When a medium flows around such a surface, it is advantageous, on account of different flow states in the different regions, if the depressions or elevations 602 in the planar region 601 differ in form and/or size and/or arrangement from the depressions or elevations 902 in the curved region 901. This may also be necessary purely for geometric reasons, since, in the case of a high curvature of the surface, for example, an appropriate size of the depressions or elevations is restricted.

Figures 13a and 13b show a model of a train with a surface which has a multiplicity of depressions. The form for the depressions used in this model corresponds essentially to

those illustrated in fig. 7, adapted to the curvature of the surface. A variation in size and distribution of the depressions between differently curved regions of the surface can also be seen.

The flow properties of this model were measured in a wind channel. This resulted in a surface resistance reduced by 16%, and in a markedly reduced formation of leeward rolls. Furthermore, measurements in a medium which had turbulent flows yielded a significant reduction in the generation of vibrations.